DUAL BAND, DUAL POL, 90 DEGREE AZIMUTH BW, VARIABLE DOWNTILT ANTENNA

PRIORITY CLAIM

This application claims priority of commonly assigned co-pending patent application Serial No. 10/085,756 filed February 28, 2002 entitled "Antenna Array Having Sliding Dielectric Phase Shifters", the teachings of which are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention is generally related to antennas, and more particularly, to mobile communication antennas including dual band, dual pol, variable downtilt antennas usable in PCS (1900 HZ) and cellular (800MHz) wireless communication networks.

BACKGROUND OF THE INVENTION

Wireless mobile communication networks continue to be deployed and improved upon given the increased traffic demands on the networks, the expanded coverage areas for service and the new systems being deployed. Cellular type communication systems derive their name in that a plurality of antenna systems, each serving a sector or area commonly referred to as a cell, are implemented to

effect coverage for a larger service area. The collective cells make up the total service area for a particular wireless communication network.

Serving each cell is an antenna array and associated switches connecting the cell into the overall communication network. Typically, the antenna array is divided into sectors, where each antenna serves a respective sector in the cell. For instance, three antennas of an antenna system may serve three sectors, each having a range of coverage of about 120°. These antennas are typically vertically polarized and have some degree of downtilt such that the radiation pattern of the antenna is directed slightly downwardly towards the mobile handsets used by the customers. This desired downtilt is often a function of terrain and other geographical features. However, the optimum value of downtilt is not always predictable prior to actual installation and testing.

Thus, there is always the need for custom setting of each antenna downtilt upon installation of the actual antenna. Typically, high capacity cellular type systems can require re-optimization during a 24 hour period. In addition, customers want antennas with the highest gain for a given size and with very little intermodulation (IM). Thus, the customer can dictate which antenna is best for a given network implementation.

Moreover, multiple bands of service need to be provided to each cell, including, but not limited to PCS and cellular. Dual band dual pol antennas continue to require further technical capabilities, including being housed in a single antenna structure. To date, there is no known Dual band, dual pol variable downtilt antenna that has a 90 degree azimuth beamwidth. The present invention is such a device.

SUMMARY OF THE INVENTION

The present invention achieves technical advantages as a dual band, dual pol, variable downtilt antenna having a microstrip feed network formed upon a PC board, and having horizontal dielectric elements slidable upon the microstrip feed network to achieve uniform phase shift and downtilt. Advantageously, the dielectric members are slidingly disposed upon serpentine portions of the microstrip feeding respective dipole elements to achieve uniform downtilt adjustment while using a microstrip architecture. Advantageously, this dual band, dual pol antenna achieves a complete 90 degree azimuth beamwidth which heretofore has never been provided in one device, especially with a device having variable downtilt.

In one preferred embodiment, the antenna includes a first set of dipole elements forming a first band such as a PCS band antenna, and a second set of dipole elements forming a second band such as a cellular band antenna. The second band is collectively configured as two linear arrays of antenna elements arranged parallel to a center line of dipole elements forming the PCS band antenna, the elements of one array being 90° with respect to the other array of antennas. Advantageously, the dipole elements of each band are fed by a microstrip network formed upon a conventional PC board. The microstrip feed network of each band has serpentine portions with a dielectric material slideable thereover to achieve the necessary phase shifting of the beam pattern formed by each band of the antenna. Advantageously, a linear downtilt of up to 10 degrees is obtainable for the cellular band and up to 8 degrees for the PCS band, with a horizontal 90 degree azimuth beamwidth for each band in an overall package having a width of only 13 inches. The serpentine portions of the microstrip provide the necessary length of the fed while reducing the area needed on the PC

board, and cooperate with the dielectric materials slideable thereover.

According to another embodiment of the present invention, a single handle member is coupled to two different elongated members coupled to and slideably positioning the respective dielectric materials over the respective serpentine microstrip areas for each band. A loop handle member is coupled to a transverse member to form a rigid adjustment mechanism to phase shift the downtilt of the respective band.

According to yet another embodiment a dipole antenna is provided having two poles capacitively coupled to each other, and to a feed network.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of the dual band, dual pol, 90 degree azimuth bandwidth, variable downtilt antenna according to the present invention;

Figure 2 is a top view of the antenna of Figure 1 illustrating the serpentine portions of the microstrip having a respective dielectric member slideable thereover and feeding the associated dipole elements;

Figure 3A is a schematic diagram of the 10 element array PCS band antenna seen to have a primary dielectric member slideable over a center serpentine portion, this center portion feeding the end dipole elements via a respective serpentine microstrip portion having a slideable dielectric thereover, with a phase shift of the center antenna portion having a 3:1 ratio with respect to the end antenna elements;

Figure 3B is a schematic diagram of the 5 element array cellular band antenna seen to have a primary dielectric member slideable over a center

serpentine portion, this center portion feeding the end dipole elements via a respective serpentine microstrip portion having a slideable dielectric thereover, with a phase shift of the center antenna portion having a 3:1 ratio with respect to the end antenna elements;

Figure 4 is a blown up view of the serpentine microstrip portion feeding the antenna elements of the cellular band antenna, and the serpentine microstrip portion feeding the dipole elements of the outer PCS band antenna, each serpentine microstrip portion having respective a slideable dielectric disposed thereover;

Figure 5 depicts the two elongated fiberglass rods adhesively coupled to the respective dielectric material elements which are slideable over the respective serpentine microstrip portions of the PCS band antenna, the rods being fixed with respect to each other via a cross member adapted to receive the ends of the U shaped handle shown in Figure 1;

Figure 6 is a view of one rod having the associated dielectric material adhesively adhered thereto and adapted to be disposed over the serpentine microstrip portions of the cellular band antenna;

Figure 7 is a blown up view of a resilient member bridged across one of the shifter rods and biasing with a slight force the rod onto the serpentine microstrip therebelow to maintain the dielectric material against the serpentine microstrip;

Figure 8 is a blown up view of the two U-shaped handles that are slideably disposed within the proximal end portion of the antenna assembly, one being connected to each of the two respective rods including the dielectric members for

longitudal shifting thereover;

Figure 9 is a perspective view of a unique dipole antenna having a first element capacitively coupled to the second element, and whereby one arm of the element is angled at 45 degrees with respect to horizontal and the other arm of the element;

Figure 10 is a front view of the dipole element of Figure 9 coupled to the PC board such that one element of the dipole is capacitively coupled to the associated microstrip, and the other dipole element coupled to the ground plane extending under the PC board;

Figure 11 is a back view of the dipole element of Figure 9 illustrating the dipole element being capacitively coupled to the microstrip feed network on the PC board via the Balun foot ;

Figure 12 is a perspective view of the dipole element of the cellular band;

Figure 13 is a perspective view of a basic arch bridging across the antenna assembly at the distal end of the antenna as shown in Figure 1;

Figure 14 is a perspective view of the unique arch element disposed proximate the U-shaped sliding arms, and having a variable width as shown to provide isolation for both the PCS and cellular band antenna arrays;

Figure 15 is a graph illustrating the available 10 degree downshift of the cellular band antenna while maintaining uniform side lobes; and

Figure 16 is a graph illustrating the available 8 degree downshift of the PCS band antenna while maintaining uniform side lobes.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to Figure 1, there is generally shown at 10 a dual band, dual pol, 90 degree horizontal azimuth beamwidth, variable downtilt antenna according to the preferred embodiment of the present invention. Antenna 10 is seen to include a first linear array of dipole elements 12 forming a cellular band antenna, and two linear arrays of antenna elements 14, one linear array arranged each side of the first linear array 12 and together forming dipole elements forming a PCS band antenna. For purposes of clarity, the antenna elements 14 along the nearside of the antenna have been omitted in this Figure 1 to depict the various features of the antenna 10, including the microstrip feed system feeding each of the respective antenna arrays and formed upon respective PC boards having a backplane thereunder.

Advantageously, a first microstrip feed network has a pair of first serpentine portions 20 feeding the center dipole element 12. Each first serpentine portion 20 feeds a pair of secondary microstrips having corresponding serpentine portions 22 and 24 feeding a respective pair of dipole elements. Slidingly disposed over each first serpentine portion 20 is a first dielectric member 30, and disposed over the second and third serpentine portions 22 and 24 is a respective second and third dielectric member 32 and 34. A first and second fiberglass rod member 40 and 42 are seen to extend longitudinally each side of the first array of antenna elements 12, and extending over and adhesively secured to the top portions of the respective sliding dielectric members 30, 32 and 34 as shown. A cross member 44 is securely coupled to and bridged between the first and second rod 40 and 42, and coupled to a handle member 46 having a handle 48 at the proximal end of the antenna 10, as shown.

Advantageously, handle 48 can be retracted from or inserted towards a proximal end 47 of antenna 10 to correspondingly and in unison slide the first, second and third dielectric members 30, 32 and 34 over respective portions of the serpentine microstrip portions to linearly and selectively establish the downtilt of the beam formed by the first PCS antenna array. As shown, there is a zero degree downtilt with each of the dielectric members fully retracted from the respective serpentine portion of the microstrip feed portion. As handle 48 is retracted, each of the first, second and third dielectric members 30, 32 and 34 are advanced over the respective serpentine portion of the microstrip feed system from the distal end thereof. The more that the dielectric members are advanced over the serpentine portions of the feed network the greater the downtilt. In the maximum setting, with handle 48 fully retracted, a downtilt of 8 degrees is obtainable. Advantageously, the U-shaped handle member 46 is rigidly coupled to the cross member 44, which in turn is rigidly coupled at a corresponding and opposite portion of the respective rods 40 and 42 such that each rod 40 and 42, and the associated dielectric elements 30, 32 and 34, are all linearly advanced in uniform to achieve a very controllable downtilt and uniform beam pattern.

Still referring to Figure 1, as previously mentioned, there is shown a second array of antenna dipole elements 14 that are likewise by a second microstrip network having a plurality of serpentine microstrip portions. As shown, there are 10 antenna dipole elements 14 arranged on each side of the first PCS band dipole elements, one collinear set of elements 14 on one side extending 90° with respect to the collinear elements 14 on the other side of the PCS dipole elements 12. A pair of first serpentine microstrip portions 50 feed each of the respective two middle dipole elements 14, with one first microstrip portion 50 being formed on each side of the assembly as shown. A pair of second microstrip

portions are shown at 52 on each side of the assembly, and each feed the respective four distal antenna dipole elements 14. A pair of third microstrip portions 54 are provided at the proximal end of the antenna 10 and likewise feed the four respective dipole elements 14 thereat.

Similar to the sliding dielectric arrangement of the PCS band antenna, there is provided a pair of first dielectric members 60 adapted to selectively advance over the respective first microstrip portions 50. Similarly, there is provided a pair of second dielectric members 62 adapted to be advanced over the respective second microstrip portions 52. At the proximal end of antenna 10 is seen a pair of third dielectric members 64 adapted to be selectively advanced over the respective third microstrip portions 54. Longitudinally extending at each side of antenna 10 is seen to be a pair of rods 70 and 72 formed of a non-conductive material, such as fiberglass. Each of these respective rods 70 and 72 extend over and are adhesively secured to the top of the respective first, second and third dielectric members 60, 62 and 64. Securingly extending between and bridging the rods 70 and 72 is a rigid cross member 74 as shown. A second U-shaped handle member 76 is seen to have each end thereof secured to the cross member 74 and sufficiently spaced so as to form a rigid T-connection and avoid skewing of the rods 70 and 72 when longitudinally advanced by a handle 78. As shown, the cellular band antenna has zero degree downtilt, and by retraction of the handle 78 to advance each of the respective first, second and third dielectric members 60, 62 and 64 over the respective serpentine portions 50, 52 and 54, the selective downtilt can be uniformly adjusted up to a 10 degree downtilt.

Referring to Figure 2, there is shown a top view of the assembly 10 further illustrating the dipole element 12 and 14 locations, the microstrip feed systems feeding each of these antenna dipole elements, and the slideable dielectric

members disposed proximate thereof, and adapted to be advanced over each of the microstrip portions by retracting the respective handle 48 and 78.

One key advantage of the present invention is that the entire microstrip feed network to the dipole elements is fabricated upon the same PC board portions 18 with the PC board being the dielectric material between the ground plane 16 extending therebehind. This provides a complete dual band cellular/PCS antenna on a single PC Board, which is a space saving feature. In addition, the feed network is combined with the phase shifters on the single PC board. microstripmicrostripThe present invention advantageously integrates the feed network on the PC board by arranging the microstrips in serpentine arrangements to obtain the needed microstrip length to maintain phase alignment of the antenna dipoles.

As graphically depicted in Figure 3, which schematically depicts the PCS band antenna array, but which applies in concept to the cellular band antenna array, a signal is feed at 38 to the middle dipole element (s). The corresponding first dielectric member 30 is slideable over the Y connection (splitter) of the feed network feeding each of the end dipoles antennas. Importantly, there is a 3:1 phase shift relationship between the middle phase shifters and the outer phase shifters. Specifically, for every one degree of phase shift of the middle phase shifter, there is a three degree shift of the outer phase shifters. This phase shifter technology advantageously allows linear phase progression of the elements throughout the array. In addition, this design requires only 3 phase shifters to feed 5 elements of the cellular band antenna, and only 3 phase shifters to feed 10 elements of the PCS band antenna.

Referring back to Figure 2, there is appreciated that all of the microstrip

traces forming the feed network of both antenna arrays are carefully laid out in length so as to obtain the needed phase shift requirements, but without creating a unnecessarily large antenna 10. Advantageously, the PC boards achieve and overall width of dual band antenna 10 that is only 13 inches.

Referring to Figure 4, there is shown a blown up view of the center dipole element 12 of the cellular band antenna, and two middle dipole elements 14 of the lower array forming part of the PCS band antenna. As can be appreciated, all of the sliding rods are parallel to each other, and secured upon the top of the respective dielectric member with an appropriate adhesive such as manufactured by 3M corporation.. It is critical that the rods maintain alignment and attachment to each of the dielectric members, and the present invention accommodates this without using hardware by using an adhesive with dielectric properties commensurate with the rigid requirements of a uniform dielectric to achieve phase shift as discussed. As seen, secured at spaced intervals over each of these guide rods is a resilient member 90 bridged across each of the guide rods and providing a biasing force against the underlying rod to urge it against the respective PC board and the dielectric members upon the respective serpentine microstrip portions to prevent separation therefrom. Interposed between the serpentine microstrip portions and the respective sliding dielectric member is a low friction member, preferably comprised of Teflon® tape, secured over the serpentine portion, but which may also be applied to the bottom surface of the sliding dielectric member if desired.

microstripmicrostripmicrostripmicrostripmicrostripmicrostrip

Turning now to Figure 5, in view of Figure 3A, there is shown a perspective view of the two outer guide rods 70 and 72 being securingly bridged

together by the member 74. Also shown is the respective first, second and third dielectric members 60, 62 and 64 being adhesively secured to the bottom side of the rods and extending collinear with the guide rods 70 and 72. This dielectric slide rod assembly is generally depicted at 100.

Turning now to Figure 6, in view of Figure 3B, there is shown one of the two guide rods 40 extending collinear with and adhesively secured to the respective first dielectric members 30, 32 and 34. It is noted that the dielectric constant for each of these dielectric members is preferably 3.0 for the second and third dielectric members 32 and 34, and 10.0 for the middle dielectric member 30 to obtain the 3:1 phase ratio between the phase shifters 30, 32 34 as previously discussed. Likewise, the dielectric constant of the second and third dielectric members 62 and 64 for the cellular band is 3.0, where the dielectric constant of the first dielectric member 60 is preferably 10.0 as well.

As shown in Figure 7, these resilient members 90 are slightly arched when bridged over the respective guide rod to provide the downward biasing force. Advantageously, this arrangement does not require any hardware being connected to the guide rods which maintains the integrity thereof. Also shown in Figure 4 is the two serpentine microstrip portions feeding each pole of the center dipole antenna 12 of the PCS band, these microstrip portions being shown at 90 and 92. Also shown in Figure 4 is one first microstrip portion 50 feeding the two middle antenna dipole elements 14 of the PCS band via a T-connection (splitter) shown at 96, and feeding a pair of respective serpentine microstrip portions 98 and 99 feeding the respective dipole elements 14. Advantageously, the length of each microstrip 98 and 99 is slightly different to optimize the vertical pattern for the mid- tilt position. The middle microstrip portions 92 and 94 also have the same length.

Referring to Figure 8, there is shown an enlarged view of the phase shift handles 48 and 78 which further are provided within indicia 102 to indicate the downtilt of the respective antenna array. This indicia 102 that is visible proximate the proximal end 47 of antenna 10 identifies the downtilt of the respective antenna. Locking pins 104 are provided with eye loops 106 to lock the handle in place upon establishing the desired downtilt, and are extended through the respective hole 108 defined through the U rod as shown.

Turning now to Figure 9, there is depicted a perspective view of one antenna element 14 forming half of the collective dipole antenna formed in conjunction with the opposing antenna element 14 rotated 90° of the PCS band antenna. Ten (10) of these antenna dipole elements 14 are linearly positioned each side of the cellular band antenna elements 12, with one linear array having the elements rotated 90° with respect to the top other linear array. Advantageously, an outer arm 110 of each antenna element 14 is seen to extend downwardly at 45 degrees with respect to horizontal, and the opposing arm 112 for the particular antenna element 14. This antenna element 14 with one 45 degree arm improves co-polarization/cross polarization ratio near the sector edge of the PCS band antenna.

Also shown in Figure 9 is a Balun 114 having a hook shape that is capacitively coupled to the antenna element 14 and positioned coplanar therewith. This capacitive coupling is achieved using an RF clear spacer members 116 to establish the air gap therebetween. Turning now to Figure 10, there is shown one dipole element 14 secured to the PC board 18 of antenna 10 and to the ground plane 16 as shown. The Balun 114 is seen to be capacitively coupled to the corresponding microstrip via a ceramic dielectric member 116.

Referring to Figure 11, there is shown the other side of the antenna dipole element 14 with the first dipole element including the 45 degree arm 110 and the opposing arm 112 being secured at a bottom end thereof to the ground plane. The metal-to-metal contact of the foot of the element to the ground plane 16 is localized to reduce IM.

Referring now to Figure 12 there is shown a perspective view of one dipole antenna 12 having a pair of radiating elements, and including reflector elements each having an arm extending downward at least 45° with respect to horizontal as previously described with regards to Figure 9. The pair of Baluns shown at 120 and 122 and seen to be capacitively coupled to the radiating vertical elements 124 and 126. The radiating elements 120 and 122 are both capacitively coupled to the respective microstrip, while the reflector elements 124 and 126 are connected directly to the groundplane 16.

Referring now to Figure 13 there is shown a perspective view of an arch support member 128 shown extending across the distal end of antenna 10. As shown, this arch is curved, and has a uniform width W as shown. This arm is provided to improve isolation of both the cellular band antenna, and the PCS band antenna.

Referring now to Figure 14, there is shown the proximal arch 130 uniquely designed to have a varying width, as shown. Particularly, the arched member 130, formed of an electronically conductive material, such as bent sheet metal, is seen to ratchet between a narrow width and a wider width as it extends from each end thereof. The two widest portions of the arch 130, shown at 132, are seen to have a width approximately twice as wide as the center portion 134. The two middle sections 136 have the same width as the end portions 138.

This is to achieve isolation (30 dB minimum) between 2 ports (+45 & -45) of the PCS band array and between 2 ports (+45 & -45) of the cellular band array.

Referring now to Figure 15, there is shown the vertical beam pattern of the cellular antenna and the selectable downtilt being selectable between 0 and 10 degrees. Likewise, as shown in Figure 16 there is depicted the vertical beam pattern of the PCS antenna array having a selectable downtilt from 0 to 8 degrees.

With emphasis, and advantageously, the present invention provides a dual band, dual pol, variable downtilt antenna, and importantly, having a 90 degree azimuth beamwidth which prior to the present invention has never been provided in a single device. A 65° degree beamwidth is the best known to the inventors. Thus, one of the technical advantages of the present invention is a 90 degree azimuth beamwidth antenna that has been uniquely engineered and designed to provide all four features. This goal has not been obtainable to date due to all the other RF requirements, RF limitations, and particular designs of past antennas.

Though the invention has been described with respect to a specific preferred embodiment, many variations and modifications will become apparent to those skilled in the art upon reading the present application. It is therefore the intention that the appended claims be interpreted as broadly as possible in view of the prior art to include all such variations and modifications.